



RESEARCH

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DETERMINING THE APPLICABILITY OF X*TRAX™ FOR ON-SITE REMEDIATION OF SOIL CONTAMINATED WITH ORGANIC COMPOUNDS

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For On-Site Remediation of Soil
Contaminated With Organic Compounds**

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1.0 INTRODUCTION

The market for soil treatment technologies is expanding rapidly. One source estimates the contaminated soils market to be \$200-300 billion in the next 30 to 40 years.¹ This market expansion is driven by at least three factors. First is the Superfund program, of which contaminated soils comprise the majority of wastes requiring remediation of hundreds of sites across the country. A second driving force is the "landbans" (40 CFR Part 268) which will prohibit the landfilling of many contaminated soils because of their organic content. The third driving force is the recent legislation by many states requiring that real estate must be certified as non-contaminated before the transfer takes place.

Many technologies can potentially be used to treat organically-contaminated soils. These include solidification/stabilization, bioremediation, soil washing, in situ vacuum extraction, solvent extraction, thermal desorption (stripping), in situ and ex situ vitrification, incineration and others.

This paper will focus on the types of contaminated soils that are likely candidates for low temperature thermal desorption. The data presented and conclusions drawn apply only to the patented X*TRAX™ process developed by Chemical Waste Management, Inc. (CWM).

2.0 PROCESS DESCRIPTION

Chemical Waste Management initiated development of its low temperature thermal treatment process, X*TRAX, in 1987 after laboratory testing by CWM had shown that at the relatively low temperatures of 250-450°C (475-850°F) many organic compounds, including high boiling compounds (PCBs), could be successfully separated from solids such as soils and sand. Since then, a process has been defined and scaled

up to a 115 metric tons per day commercial unit. U.S. Patent No. 4,864,942 has been granted for the process.

The process can handle soils and dewatered solids such as pond sludge and filter cakes. Organic contaminants can range from high boiling, semi-volatile compounds such as PCBs, to low boiling, volatile compounds such as RCRA regulated solvents.

In the course of the development effort, treatment systems have been built at three distinct sizes, termed laboratory scale, pilot scale, and commercial. The two laboratory units are used for performing bench-scale treatability studies. One unit is operated by a CWM company called Chem-Nuclear Systems, Inc. (CNSI) for performing treatability studies on mixed (RCRA and radioactive) wastes. The other unit is operated by CWM's Research and Development Division located in Geneva, IL. This unit is used for RCRA and TSCA materials and is fully permitted. The pilot scale system was used to confirm the design parameters and is now used as a demonstration unit. The first commercial unit has been completed and will be moved to a Superfund site during the second quarter of 1991.

The X*TRAX process uses an indirectly heated rotary dryer to volatilize the water and organic contaminants in a sealed system. The hot treated solids are cooled and dedusted using the condensed water removed from the feed. An inert carrier gas (nitrogen) transports the volatilized components to a gas treatment train. The gas treatment train removes the entrained particulate solids with a scrubber and then cools the entire gas stream to less than 5°C (40°F) to condense the volatilized organics. Ninety to ninety-five percent of the carrier gas is reheated to 315°C (600°F) and recycled to the dryer. The remainder of the carrier gas passes through a 2 micron filter and a carbon adsorption system before being discharged to the atmosphere. The condensed liquid organic removed from the soil is disposed off-site. Detailed descriptions of the X*TRAX systems have been presented in previous papers.^{2,3}

3.0 SOIL CHARACTERISTICS

Contaminated soil at a remediation site is rarely homogeneous and frequently contains solid debris. Naturally occurring sandy locations may have areas of high clay content and vice-versa. On-site remediations may require as little as the top six inches to be treated, or as much as ten to twenty feet may have to be excavated. It is possible to encounter rich topsoil, clay, and sand when excavating only a few feet. In addition, many remediation sites have areas of engineered fill that may contain compacted clay, sand, gravel, and even building rubble. Suitable ex-situ on-site treatment technologies will ideally handle all of the variabilities in soil condition and makeup that may be encountered after the oversize material is removed or crushed.

Virtually all ex situ technologies will have a maximum particle size that can be fed to the process. The maximum size generally ranges from 1/2" to 3". Before pretreatment can begin, any underground tanks, vaults, or containers must be removed. In locations where the soil is primarily sand, a simple screening operation will usually suffice. The X*TRAX process requires screening to less than two inches. When clays are encountered, a soil shredder may be required. This will depend on the type of clay and its moisture content. In either case, the screened material should be stored under a canopy to prevent rainfall from increasing the moisture content and to reduce the amount of contaminated water that must be handled.

When very large rocks or building rubble is encountered, three options may be available. The most desirable solution is to return the oversize material to the excavation. In many cases, the large rocks or cement pieces do not contain a significant amount of organic contamination, though testing on a site-specific basis is usually necessary in order to confirm this. If this approach is not acceptable to the regulatory agencies, then the oversize material can be transported off-site to a suitable landfill or crushed on-site and treated. The last two options are highly site-specific.

The soil type has a significant effect on process rates and attainable treatment levels. The presence of clay or naturally-occurring humic material will increase the adsorptive capacity of soil.⁴ Experience has shown that soils with very high clay content are more difficult to treat than soils comprised mainly of sand or silt. An example is shown in Table 1. Both of the soils from Illinois and South Carolina had the appearance and texture of a high clay content soil. The laboratory soil characterization results have not been received yet.

Table 1. PCB Removal for Different Soil Types

Sample	Soil Location	% Moist	Initial PCB Concentration	Treated Soil Concentration (mg/kg)	% Removal
SCH32	Illinois	26	2,900 (1)	7.0	99.8
SAW	South Carolina	24	3,760 (2)	164	95.6
SAH	South Carolina	14	2,960 (3)	170	94.3

Notes: (1) Primarily Aroclors 1248 & 1254
 (2) Primarily Aroclors 1248 & 1254
 (3) Primarily Aroclor 1248

All three soil samples referenced in Table 1 were processed through the laboratory X*TRAX unit under similar conditions. The variability in residual PCB levels in the treated soils dramatically confirms the need for performing treatability studies. Both soils had similar moisture contents, PCB concentrations and PCB Aroclors, yet the Illinois soil could be treated to less than 10 mg/kg, while the two samples from South Carolina could not be treated to less than 100 mg/kg.

Soils rich in humic material, such as topsoil, should be avoided where possible. In addition to the previously mentioned increase in soil adsorptivity, many of the organic acids driven off during the thermal desorption are water soluble. The condensed

water from the process requires substantial treatment before reuse in the system or discharge. If a relatively thin layer of topsoil is present, it can be blended with the underlying soil to reduce the humic content of the feed. Any vegetative cover should be removed before excavation.

4.0 CONTAMINANTS

Contaminated soils seldom contain only a single contaminant. It is not uncommon to have more than four principle organic hazardous constituents (POHCs) along with numerous other organic compounds at measurable levels. The following sections discuss the treatability of five broad categories of contaminants, including metals.

4.1 PCBs

The X*TRAX thermal desorption process was designed to be capable of removing PCBs from soil to levels that would allow the soil to be left on-site. Since there are not many organic compounds with vapor pressures lower than the common PCB Aroclors, a process that effectively treats PCBs should be suitable for most any organic contaminant.

The ultimate goal was to be able to reduce the PCB level in any soil to less than 2 mg/kg, which is a treatment level often imposed by EPA. For soils with more than 100 mg/kg PCBs, this goal has not yet been attained. Except for a few isolated cases, the X*TRAX process has been able to reduce the PCB level to less than 25 mg/kg and frequently to below 10 mg/kg when the PCB concentration in the feed materials tested ranged from 100 to 7,800 mg/kg. Treatment levels of 10 mg/kg or 25 mg/kg are consistent with the latest EPA guidance document for remedial actions at Superfund sites with PCB contamination.⁵

Treatability studies on over sixteen samples from ten PCB-contaminated sites have been performed using the laboratory X*TRAX unit. The data from several of these treatability studies are presented in Table 2. The data show that at least a 95%

reduction can be obtained when the contaminated soil contains greater than 100 mg/kg of PCBs. These treatment levels are consistent with the Alternate Treatability Variance Levels for PCBs presented in the EPA's Superfund LDR Guide #6A.⁹ For PCB concentrations greater than 100 ppm, a 90-99.9% reduction is recommended. The X*TRAX process can certainly meet this requirement. It is interesting to note that this document does not list low temperature stripping (desorption) as a technology capable of achieving the guidelines.

The pilot X*TRAX system has processed ten different PCB contaminated soils under a one-time U.S. EPA TSCA R&D permit. The results from the pilot testing are summarized in Table 3.

Table 2. Laboratory X*TRAX Results - PCB Contaminated Soils

Sample ID	Feed PCB Concentration (mg/kg)	Product PCB Concentration (mg/kg)	% Reduction
SCH17	4.6	0.94	79.6
PB	5.2	2.0	61.5
SAD	12	BDL (1.0)	> 91.7
GMB	150	3.2	97.9
JDR	330	BDL (5.0)	> 98.5
PRY	770	12	98.4
GER	805	17	97.9
SCH32	2,900	7.0	99.8
SAH	2,960	170	94.3
SAW	3,760	164	95.6

Table 3. Pilot X*TRAX Results - PCBs

Run ID	Amount Processed (lbs)	Feed PCB Conc. (mg/kg)	Product PCB Conc. (mg/kg)	% Reduction
0921B	2,145	68	16	76.5
0124	4,205	120	3.4	97.2
0914	2,820	190	9.6	95.0
0929	2,240	630	17	97.3
0926	1,830	640	18	97.2
0727	4,940	1,480	8.7	99.1
1003	2,790	1,600	4.8	99.7
0810	4,570	2,800	19	99.3
0919	4,530	5,000	50	99.0
0122	4,750	7,800	24	99.7

Again, we see that at least 95% removal can be obtained when the PCB level is greater than 100 mg/kg. We also see that even with 7,800 mg/kg PCBs in the feed the treated soil had less than 25 mg/kg PCBs.

4.2 Pesticides

Only one pesticide contaminated soil has been tested to date. We anticipate performing two more studies in the near future. One will be at the laboratory scale and the other at both the laboratory and pilot scale. The results from the completed laboratory treatability study are presented in Table 4. For all identified pesticides at least a 97% reduction was achieved. The TCLP was also performed on the treated soil to assess whether it exhibited a toxic organic characteristic (new D codes). These results are presented in Table 5.

**Table 4. Laboratory X*TRAX Results
Pesticide Contaminated Soil**

Contaminant	Feed Concentration (ppm)	Product Concentration (ppm)	% Removal
4,4'-DDE	32	0.57	98.2
4,4'-DDD	320	1.3	99.6
Alpha-Chlordane	100	2.1	97.9
Gamma-Chlordane	110	3.0	97.3

**Table 5. Comparison of Treated Soil to
Toxicity Characteristic Regulatory Level**

EPA HW No.	Contaminant	Treated Soil (ppm)	Treated Soil TCLP (mg/L)	Regulatory Level (mg/L)
D020	Chlordane	5.1	< .0025	0.03
D031	Heptachlor	< 0.03	< .00025	0.008
D013	Lindane	< 0.03	< .00025	0.4

The TCLP concentrations for the three listed pesticides are well below the regulatory level. Although only one test has been completed, the data indicate that the X*TRAX process is suitable for certain pesticide- contaminated soils.

4.3 Semi-Volatile Organics

The samples tested at both the pilot and laboratory scale have all had relatively low levels of semi-volatile organic compounds. The results for three different compounds are presented in Table 6. Sample IDs that are letters are laboratory scale tests, and the number IDs are from pilot tests. When the concentration in the treated soil was measurable, the percentage reduction was greater than 95%. The data indicate that

most semi-volatile organic compounds can be reduced to less than 10 ppm and frequently below 1 ppm.

**Table 6. Laboratory and Pilot X*TRAX Results
Semi-Volatile Organics**

Compound	ID	Feed (ppm)	Product (ppm)	% Reduction
Bis(2-Ethylhexyl) Phthalate	SAW	3.2	BDL (.33)	> 89.7
	SAWR	3.9	BDL (.33)	> 91.5
	1003	3.4	0.30	91.2
	0727	9.1	0.18	98.0
Phenanthrene	PB	14	BDL (.33)	> 97.6
	MC	19	0.29	98.5
	MBL	30	BDL (13)	> 56.7
Naphthalene	PB	34	0.74	97.8
	MBL	110	BDL (13)	> 88.2
	MC	450	7.9	98.2

4.4 Volatile Organics

As was the case for semi-volatile organics, very few soil samples have been received that contain significant quantities of volatile organics. It is not surprising that the most often detected volatile organics were the BETXs (benzene, ethylbenzene, toluene and xylene). Several examples of removal rates are presented in Table 7. In most cases the semi-volatile organics were reduced to well below 1 ppm.

It is interesting to note that the highest volatile organic contamination levels were in the feed sample labeled SSM-1/5. The material SSM (Synthetic Soil Matrix) is a surrogate Superfund soil created for the EPA for treatability studies.⁷ CWM did not participate in the original study since it was initiated before the laboratory X*TRAX system became operational. A sample of the Type I soil was obtained from the contractors archive to be used for CWM's own testing.

**Table 7. Laboratory and Pilot X•TRAX Results
Volatile Organics**

Compound	ID	Feed (ppm)	Product (ppm)	% Reduction
Benzene	PB	0.35	BDL (.05)	> 85.7
	MC	3.0	BDL (0.10)	> 96.7
	MBL	6.9	1.6	76.8
	TFC	30	BDL (0.13)	> 99.6
	BL9	980	BDL (0.21)	> 99.98
Ethylbenzene	PB	0.40	BDL (.05)	> 87.5
	MC	13	BDL (0.10)	> 99.2
	MBL	50	0.33	99.3
	SSM-1/5	1,600	5.2	99.8
Tetrachloroethylene	SSM-1/5	150	.094	99.9
Xylene	PC	0.22	.030	86.4
	SAHK	1.6	.043	97.3
	PB	3.8	BDL (.050)	> 98.7
	BP	7.2	BDL (.095)	> 98.7
	MC	77	BDL (0.10)	> 99.9
	MBL	130	0.84	99.4
	SSM-1/5	2,400	9.5	99.6

Based on the contaminated soil samples received by CWM for testing, it appears that the actual or average organic contamination levels at many sites may be much lower than many have predicted. Consider a site with a maximum compound X concentration of 1,000 ppm that must be excavated to 10 ppm. Assuming a linear concentration, the average contaminant concentration will be 505 ppm. Since the contaminant concentration level from the source is rarely linear, the actual average concentration could be as low as 50 to 100 ppm. This should be considered when collecting samples for treatability studies. Samples from known "hot spots" should be avoided.

The sample ID BL9 in Table 7 was high in benzene. This sample was actually a pond sludge. In an actual remediation, one would not process the sludge alone, but it would be excavated and processed with the surrounding soil. This would allow for a fairly consistent feed material throughout the remediation. It does not make sense to optimize a process for 1,000 ppm of a POHC and then readjust for a feed with 10 to 50 ppm.

4.5 Metals

With the exception of mercury, the X*TRAX process will do little to remove non-volatile metals (W10) or volatile metals (W11) from contaminated soils. This should not preclude the evaluation of X*TRAX when metals contamination is significant. One of the most common treatments for metals is stabilization. Most stabilization treatments involve a pozzolanic reaction using cement, kiln dust or other materials. Organics interfere with the pozzolanic reaction. Also, stabilized samples frequently fail because of organic leaching, not metals leaching.

The treated solids exiting the X*TRAX dryer are conveyed to a mixer, where condensed water from the process is used to cool and dedust the treated soil. Normally the solids will exit the mixer with 5 to 15% moisture. Since the mixing hardware already exists, stabilization can also be performed by adding a reagent silo and a conveyor prior to the mixer. Since the majority of the organic compounds that interfere with the stabilization chemistry have been removed the reagent usage will be very low.

When metals levels are high, incineration may not be an acceptable treatment technology. Hazardous waste incinerators normally limit the metals in the feed in order to stay within the constraints of their air permit. At the low temperature that X*TRAX operates, the metals are not volatilized (except for mercury). Also, the process vent gas is filtered through a 2 micron filter before venting to atmosphere which will remove any particulate solids that may contain metals.

4.6 Other

In addition to contaminated soils, the X*TRAX process has been evaluated for one RCRA waste. Filter cakes from refinery operations carrying waste codes K048 to K050 have been tested. Two laboratory studies have been completed and a pilot test is scheduled for the second quarter of 1991.

The treated solids easily met all of the applicable BDAT requirements. The oil recovered from the phase separator had an energy content of 18,000 Btu per pound, and the condensed oil had an energy content of 15,000 Btu per pound. The filter cake from the phase separator blowdown amounted to approximately 5% of the feed and had an energy content of 8,700 Btu per pound.

5.0 SUMMARY

The CWM-developed X*TRAX process has been shown to be a suitable alternative treatment technology for a wide variety of organically contaminated soils. Successful treatability studies have been performed on soils and sludges contaminated with the following categories of contaminants:

- W01 - Halogenated Non-Polar Aromatic Compounds
- W02 - Dioxins/Furans, PCBs, and their Precursors
- W03 - Halogenated Phenols, Cresols and Other Polar Aromatics
- W04 - Halogenated Aliphatic Compounds
- W05 - Halogenated Cyclic Aliphatics, Ethers, Esters, Ketones
- W07 - Simple Non-Polar Aromatics and Heterocyclics
- W08 - Polynuclear Aromatics
- W09 - Other Non-Halogenated Polar Organic Compounds

The W06 (Nitrated Aromatic and Aliphatic Compounds) were not included in the list only because no soil samples containing any of these compounds have been tested.

PCBs were included, since most soils can be treated to less than 25 ppm and in many cases to less than 10 ppm.

Organically-contaminated soils that also contain metals may be suitable for treatment by X*TRAX with stabilization of the treated soil. The additional cost for stabilization will be small, since only minimal additional hardware is required and reagent usage will be low.

Due to the complexity and variability of contaminated soils, treatability studies are recommended. The laboratory X*TRAX system can accurately determine treatment levels. Samples for treatability studies should not usually be collected from the "hot spots." The author can be contacted for information on arranging a laboratory treatability study.

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